RESEARCH DEPARTMENT

The impairment caused by phase-perturbation of the colour sub-carrier in a colour television system of the NTSC type

RESEARCH REPORT No. EL-16

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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

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SUMMARY

This report describes subjective tests which were made to determine the picture impairment introduced when the quadrature-modulated chrominance sub-carrier in a colour television system of the NTSC type is subjected to a systematic switched phase-perturbation. The tests showed that the system is particularly susceptible to disturbances of this type, a switched phase-error of less than 1° being visible on a colour-bar test picture.

1. INTRODUCTION

In a colour television coding system of the NTSC type, separation of the two colour-difference signals in the decoder is achieved by synchronous detectors. Correct operation of these detectors requires precise control of the phase relationship between the sub-carrier reference signal fed to the detectors and the colour sub-carrier itself; an incorrect phase-relationship will result in incorrect hues in the reproduced colour picture. Phase-errors of various types can occur in practice, of which constant phase-errors, errors varying with the luminance signal level, and random errors due to noise are the most common. Information is available[1,2] concerning the permissible tolerances (determined from subjective tests) for all the above types of phase-error. However, no such information appears to be available for phase-errors which change in a systematic way at a rate comparable with the line and field frequencies of the television signal. Such errors are possible in devices such as video-tape recorders and the Field-Store Standards Converter.[3,4]

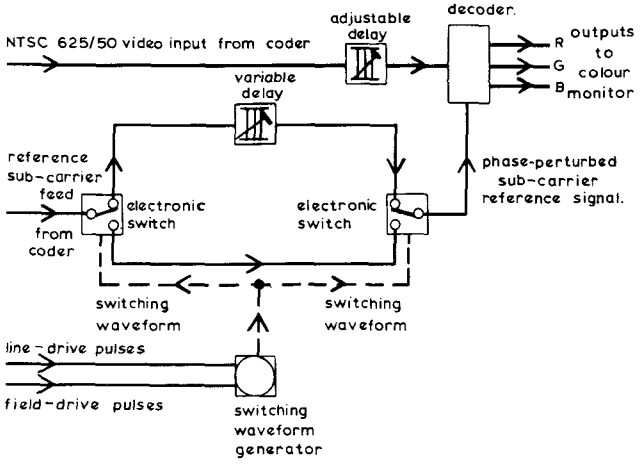

Fig. 1 - Arrangement of apparatus

This report describes an investigation carried out during the development of the advanced Field-Store Standards Converter, to determine the subjective impairment caused by switched phase-errors of the chrominance-modulated colour sub-carrier signal relative to the sub-carrier reference signal.*

2. DESCRIPTION OF THE EXPERIMENT

2.1. Arrangement of Apparatus

Subjective tests were carried out using an NTSC type, 625-line, 50 fields/second standard, and the arrangement of apparatus used for the tests is shown in Fig. 1. For instrumental convenience the normal source of reference sub-carrier provided in the decoder was replaced by direct connection from the sub-carrier generator supplying the coder. By means of the electronic switches this sub-carrier feed could be routed through either a path of fixed electrical length which provided the correct sub-carrier phase, or a path whose electrical delay could be varied. The delay in the variable path provided a reference sub-carrier phase ranging from −15° to +15°, relative to the correct phase. Care was taken to ensure that the amplitude of the sub-carrier remained constant whichever path was in use, thus avoiding any effects caused by amplitude-perturbation of the reference sub-carrier.

The apparatus thus perturbed the phase of the reference sub-carrier, rather than that of the chrominance-modulated sub-carrier as would occur in practice. However, the effects are the same and it was more convenient in the experimental arrangement to perturb the phase of the reference sub-carrier.

* Switched changes of the chrominance sub-carrier amplitude may also occur; these will be the subject of a separate report.[5]

The switches operated during line-blanking intervals and were controlled by signals from a special waveform generator. The control signals were rectangular, the rise and fall of any one waveform simulating the switching of delay-units in a field-store converter. As shown in Fig. 2, the waveforms were derived from line- and field-frequency pulses and simulated the control signals applied to the switches connecting main-store delay-units in an advanced field-store standards converter. (These delay-units would form a binary sequence of multiples of T, where $T = 66{\cdot}2/3\,\mu s$ for a converter operating between 525/60 and 625/50 standards.)[3]

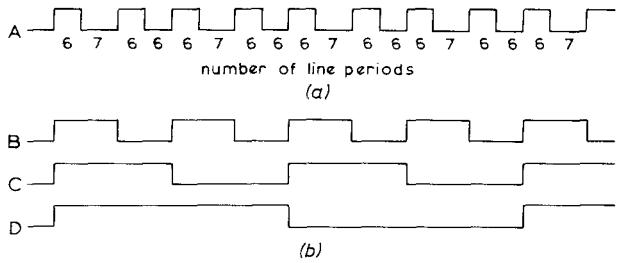

Fig. 2 - Switching waveforms

(*a*) Primary waveform derived from line sync pulses. This sequence was continued throughout five fields and after five fields the sequence was restarted. (This simulated the action of the switch controlling the delay unit of delay T in a practical standards converter.)

(*b*) Secondary waveforms derived by bistable counting circuits from A, B, C and D simulated the action of switches controlling delay units of delay $2T$, $4T$ and $8T$ in a practical standards converter. Waveforms simulating switches controlling remaining delay units were obtained by further counting circuits working in a similar manner.

2.2. Nature of Picture Impairment

In general the picture impairment caused by the switched phase-errors appeared as horizontal strips of erroneous hue moving in a vertical direction. The main characteristics of the impairment pattern for each switching waveform were as follows:

Waveform 'A' : Narrow horizontal strips of erroneous hue, changing position up and down cyclically at 5 Hz.

Waveform 'B' : Horizontal strips with a 25 Hz vertical 'judder'.

Waveforms 'C', 'D' : Broad horizontal strips moving rapidly upwards.

Waveforms simulating the control of the remaining longer delay-units produced some horizontal strips with a 10 Hz vertical 'judder'.

Preliminary subjective assessments showed, that for any given phase-perturbation, waveform 'A' produced a picture impairment pattern considerably more visible than any of the other waveforms. Consequently, the subjective tests were carried out using only this waveform.

2.3. Test Procedure

A group of five experienced observers was used for the subjective assessment of picture impairment caused by the switched phase-errors. The group observed a colour television monitor having a screen diagonal of 0·64 m (25 in); the ambient illumination was such that the luminance of the unexcited monitor screen was about 0·14 cd/m^2 (0·04 ft-L) and the displayed white brightness was about 52 cd/m^2 (15 ft-L). The observers viewed the monitor at distances ranging from three to six times the picture height.

At the start of each test the observers were shown an unimpaired picture, followed by a severely-impaired picture. They were then asked to assess the perceptibility of varying degrees of impairment using the EBU standard six-point impairment scale given below.

1. Imperceptible
2. Just perceptible
3. Definitely perceptible but not disturbing
4. Somewhat objectionable
5. Definitely objectionable
6. Unusable

2.4. Choice of Pictures Used for Tests

There were three tests; each test used a different test picture.

In the first test the picture consisted of electronically-generated, full-amplitude, 95% saturated colour-bars which, because of its freedom from noise and the intense chrominance component, was extremely susceptible to sub-carrier phase-errors; it was therefore a particularly stringent test signal.

In the two other tests the picture source was a colour slide-scanner employing electronic masking to produce highly saturated pictures, typical of those obtained from a colour television camera. One slide was chosen which was particularly susceptible to the type of picture impairment under investigation and was therefore representative of the most stringent pictures likely to occur in practice. This slide was a close-up view of a pair of ballet dancers whose costumes were of a colour near to that of the magenta colour-bar. This slide will be referred to as 'Magenta Couple.' A second slide was chosen which was fairly susceptible to

the impairment but which was more typical of pictures occurring in practice. This was a standard slide recommended by the EBU and described as 'Gloved Ski-girl holding pole - USA2.' This slide will be referred to as 'Gloved Ski-girl.'

3. RESULTS OF THE TESTS

Figs. 3, 4 and 5 show, in graphical form, the results obtained for each of the three tests. 'Best-fit' curves are drawn through plots of points corresponding to the means of the grades recorded by the observers for each test condition, separate curves being drawn for leading and lagging phase-errors.

It is of interest to note that the effects of phase-errors are asymmetrical, a leading phase-error producing a greater subjective impairment than that produced by a lagging phase-error.

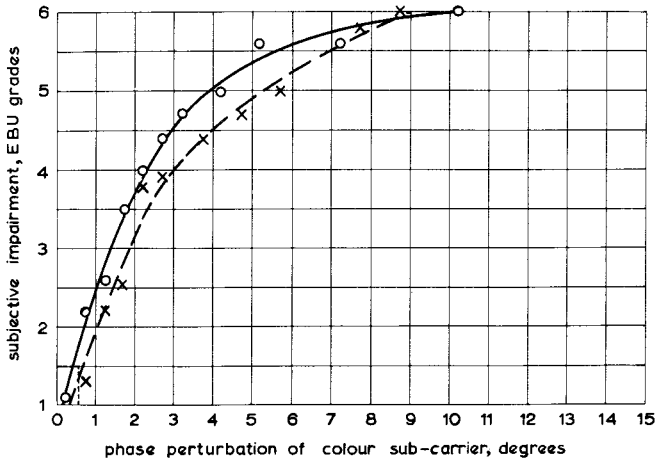

Fig. 3 - Picture impairment due to perturbation of phase of colour sub-carrier – colour bars

o——o leading phase-error
x– –x lagging phase-error

Fig. 3 shows, as would be expected, that the colour-bar signal is by far the most susceptible to switched phase-errors, the impairment being first visible in the magenta bar. If grade 1·5 is taken as a criterion, then, taking the mean of the results for lagging and leading phase-errors, the permissible error for the colour-bar test signal is only about 0·6°. For a stringent picture, 'Magenta Couple,' the permissible error is about 1·2° (Fig. 4), whilst for a typical picture, 'Gloved Ski-girl,' the permissible error can be increased to about 4·4° (Fig. 5).

4. CONCLUSIONS

The impairment caused by systematic phase-errors of the chrominance sub-carrier in a colour television system of the NTSC type has been determined by means of subjective tests. The results of these tests do not apply to phase-errors in general since the picture-impairment pattern used was that due to a particular switching waveform for use in a field-store standards converter. It is thought probable, however, that the results given in this report represent the worst case of a systematic phase-error impairment.

No attempt was made to assess the corresponding effects of perturbing the colour sub-carrier phase on the compatible monochrome picture. It is thought unlikely that any increase in sub-carrier visibility would be detected in view of the relatively small phase-changes involved.

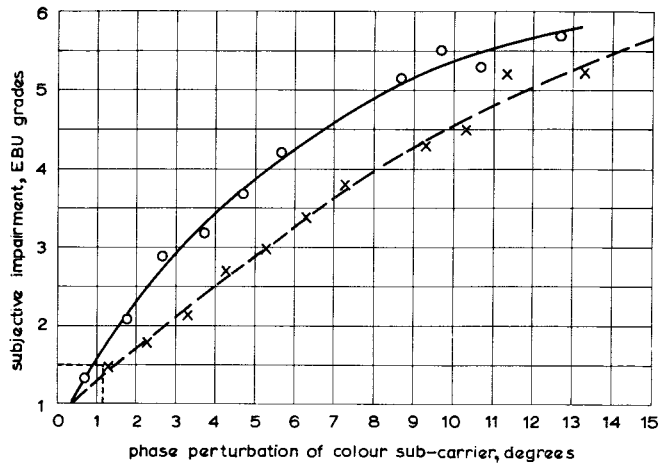

Fig. 4 - Picture impairment due to perturbation of phase of colour sub-carrier – 'Magenta Couple'

o——o leading phase-error
x– –x lagging phase-error

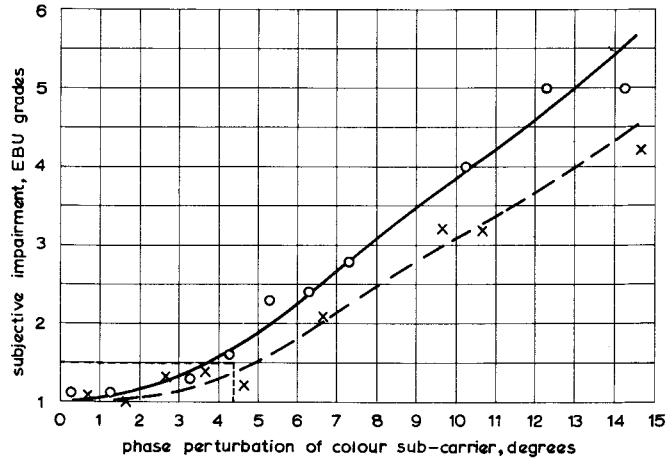

Fig. 5 - Picture impairment due to perturbation of phase of colour sub-carrier – 'Gloved Ski-girl'

o——o leading phase-error
x– –x lagging phase-error

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